Photoproduction of K* for the study of Λ(1405)

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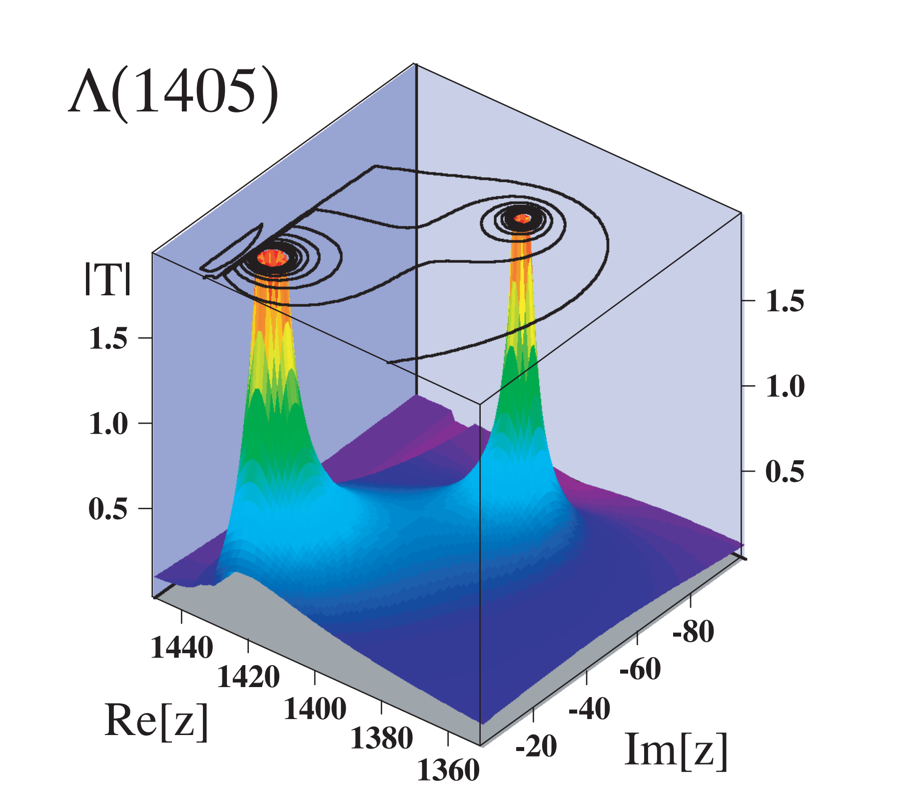
Motivation : Two poles?

There are two poles of the scattering amplitude around nominal Λ(1405) energy region.

- **Cloudy bag model**
  J. Fink, *et al.*, PRC41, 2720
- **Chiral unitary model**
  J. A. Oller, *et al.*, PLB500, 263
  E. Oset, *et al.*, PLB527, 99
  D. Jido, *et al.*, PRC66, 025203
  T. Hyodo, *et al.*, PRC68, 018201
  C. Garcia-Recio, *et al.*, PRD67, 076009
  D. Jido, *et al.*, NPA725, 181
  T. Hyodo, *et al.*, PRC68, 065203
- **Quark model : qq-qq-$\bar{q}$**
  A. Zhang, *et al.*, hep-ph/0403210

$\Lambda(1405) : J^P = 1/2^-, I = 0$



ChU model, T. Hyodo

Chiral unitary model

Flavor SU(3) meson-baryon scatterings (s-wave)

Chiral symmetry

Low energy behavior

+

Unitarity of S-matrix

Non-perturbative resummation

Dynamical generation →

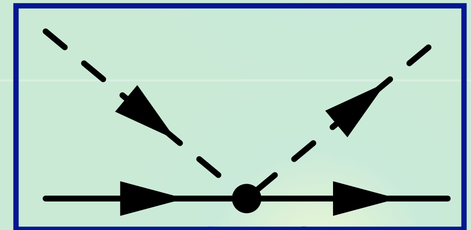
$J^P = 1/2^-$ resonances

$\Lambda(1405), \Lambda(1670),$
$\Sigma(1620), \Xi(1620),$
$N(1535)$

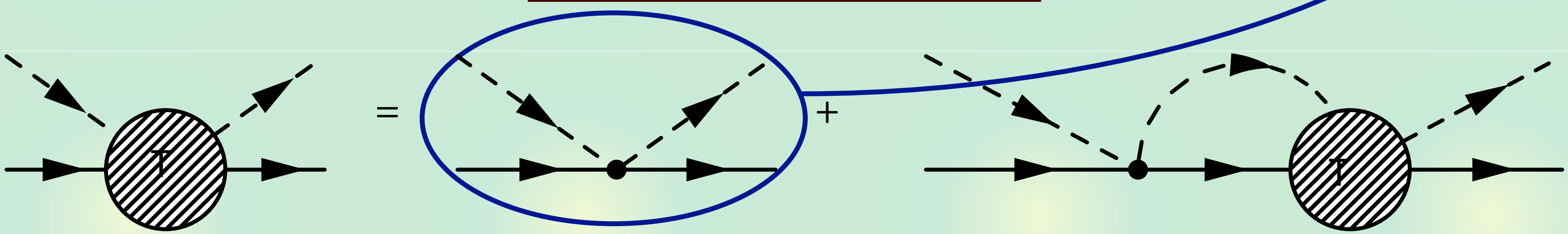
Framework of the chiral unitary model

Chiral perturbation theory

$$\mathcal{L}_{WT} = \frac{1}{4f^2}\mathrm{Tr}(\bar{B}i\gamma^{\mu}[(\Phi\partial_{\mu}\Phi - \partial_{\mu}\Phi\Phi), B])$$

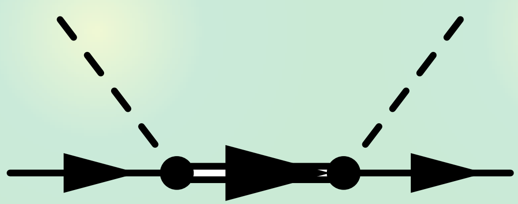


Unitarization



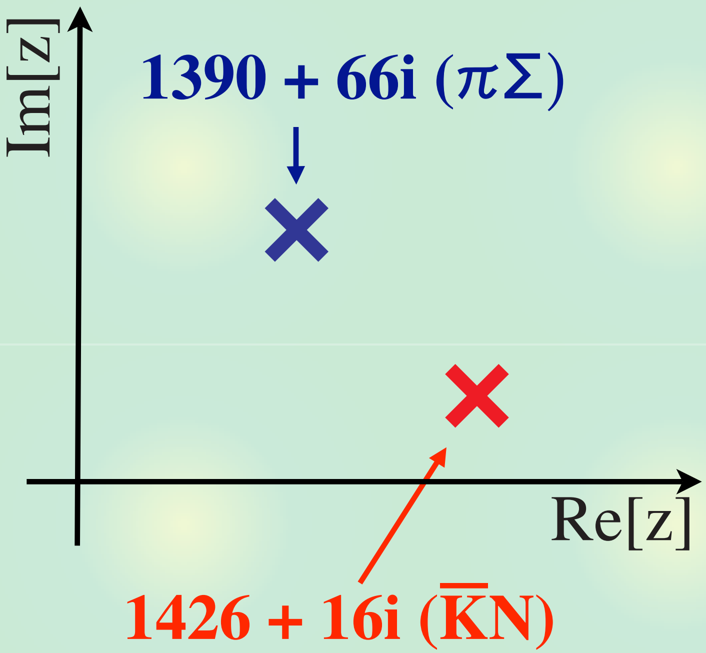
$$T_{ij}(\sqrt{s}) \sim \frac{g_i g_j}{\sqrt{s} - M_R + i\Gamma_R/2} + T_{ij}^{BG}$$

$\sim$

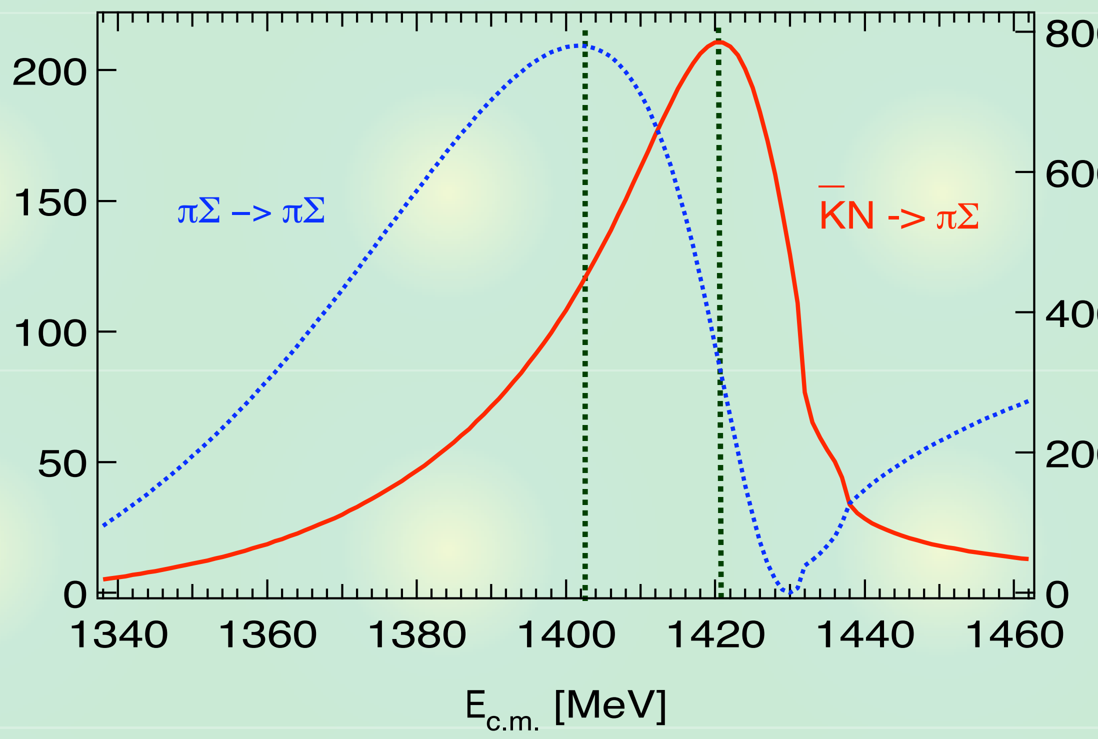


Λ(1405) in the chiral unitary model

position of poles



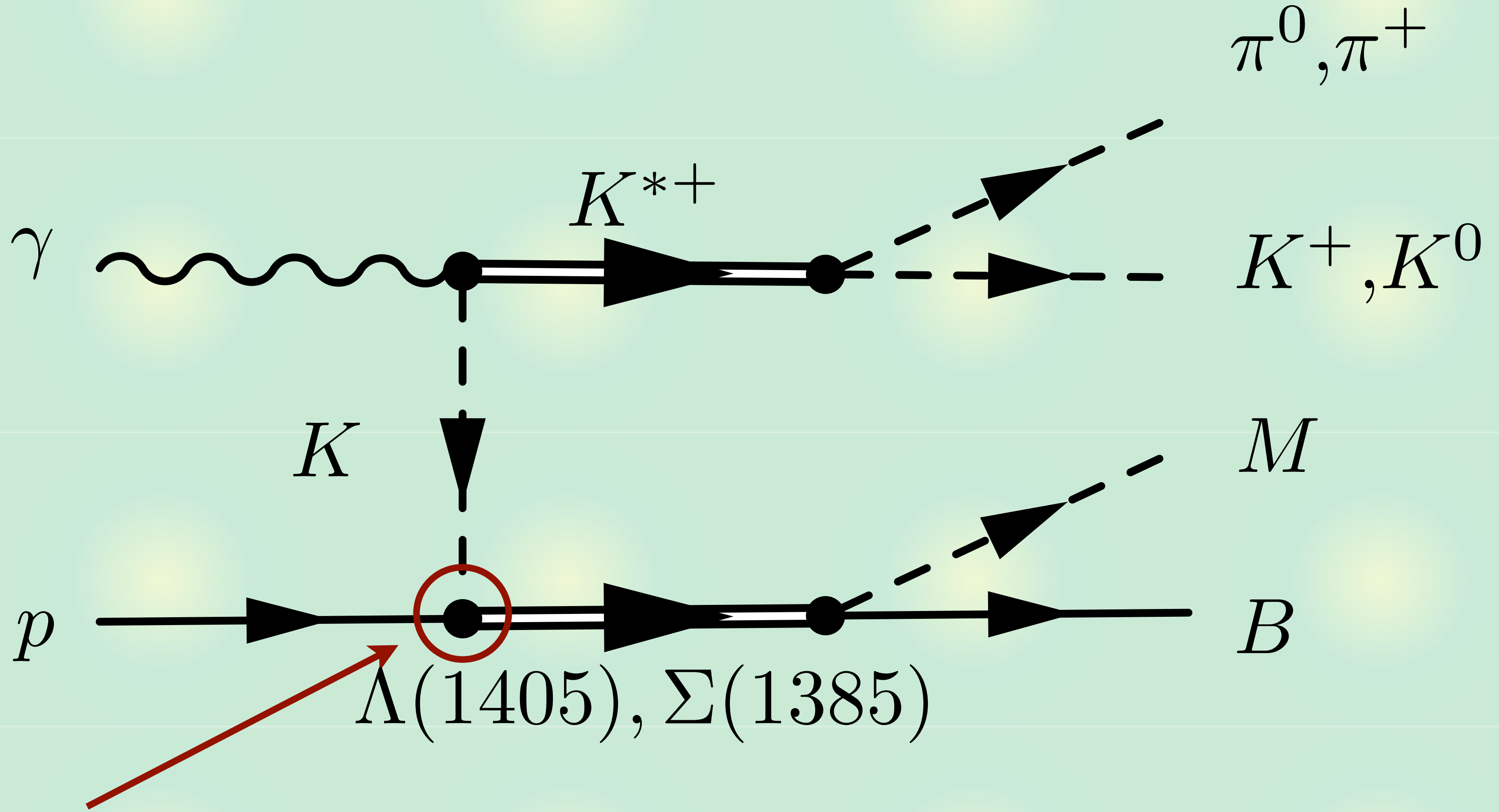
πΣ mass distribution



$$\frac{d\sigma}{dM_I} = C|t_{\pi\Sigma\to\pi\Sigma}|^2 p_{CM} \quad \Rightarrow \quad \frac{d\sigma}{dM_I} = |\sum_i C_i t_{i\to\pi\Sigma}|^2 p_{CM}$$

D. Jido, *et al.*, Nucl. Phys. A 723, 205 (2003)

Photoproduction of K* and Λ(1405)

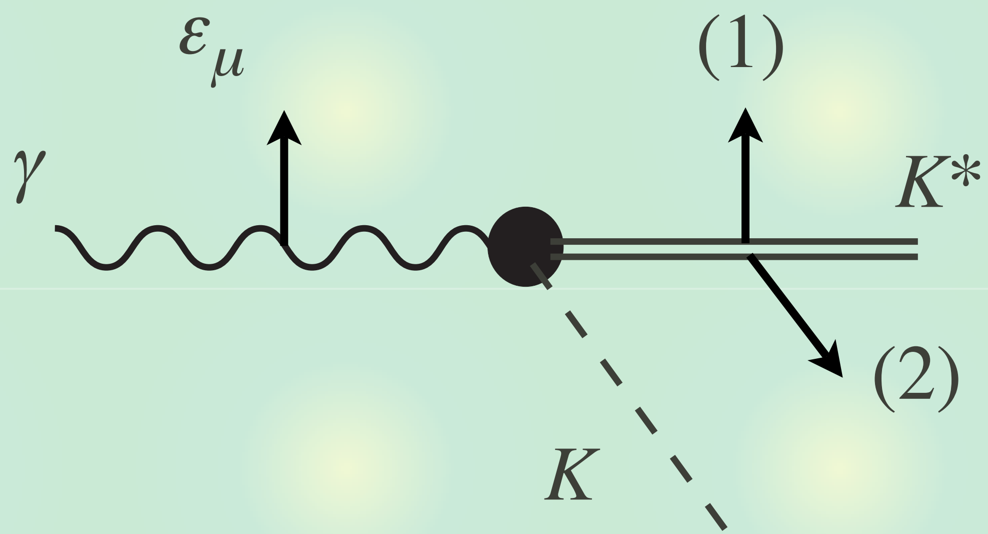


Only K⁻p channel appears at the initial stage

Higher energy pole ??

Advantage of this reaction

There is a correlation between polarization of initial photon and final πK angular distribution



$$(1)\quad \varepsilon_\mu(K^*)\,//\,\varepsilon_\mu(\gamma)\quad : J^P = \text{natural}$$

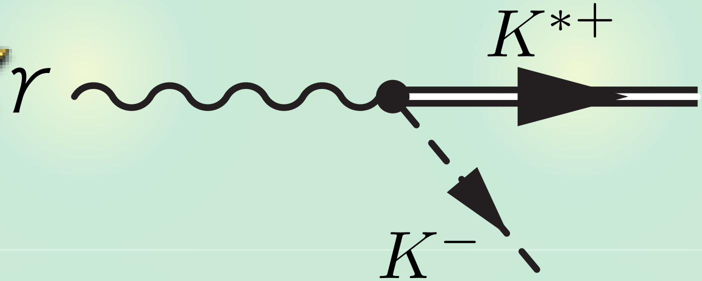
$$(2)\quad \varepsilon_\mu(K^*)\perp\varepsilon_\mu(\gamma)\quad : J^P = \text{unnatural}$$

Clear mechanism

Effective interaction for meson part

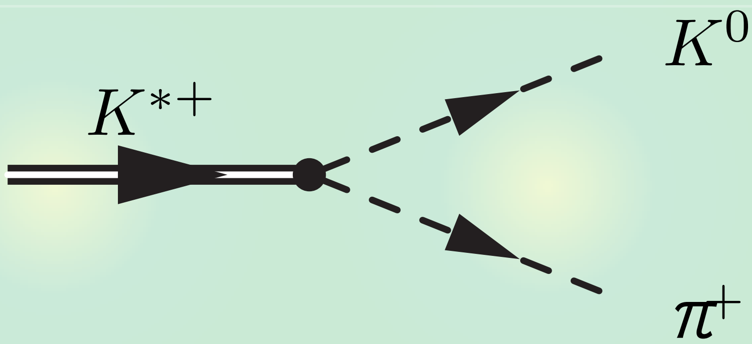
★ γKK* coupling

$$\mathcal{L}_{K^*K\gamma} = g_{K^*K\gamma}\epsilon^{\mu\nu\alpha\beta}\partial_\mu A_\nu(\partial_\alpha K^{*-}_\beta K^+ + \partial_\alpha \bar{K}^{*0}_\beta K^0) + \text{h.c.}$$

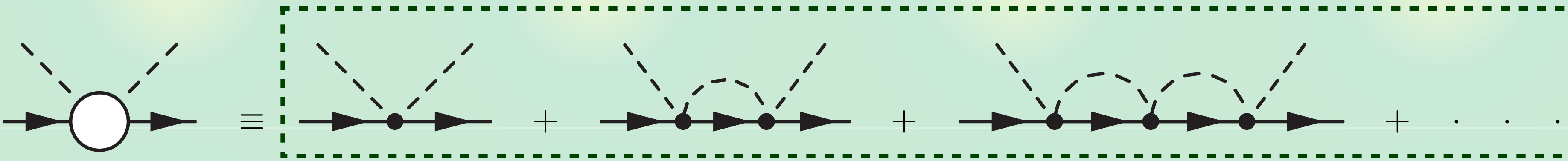


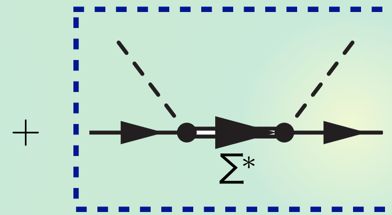
★ VPP coupling

$$\mathcal{L}_{VPP} = -\frac{ig_{VPP}}{\sqrt{2}}\text{Tr}(V^\mu[\partial_\mu P, P])$$



Effective interaction for baryon part





ChU amplitude

Σ(1385) pole term

☆ **Σ(1385)MB coupling**

☆ $$-it_{\Sigma^* i} = c_i \frac{12}{5} \frac{D+F}{2f} \boldsymbol{S} \cdot \boldsymbol{k}_i$$

☆ **form factor**

$$F_f(k_1) = \frac{\Lambda^2 - m_K^2}{\Lambda^2 - (k_1)^2}$$

Isospin decomposition of $\pi\Sigma$ states

Since initial state is $\bar{\mathrm{K}}\mathrm{N}$, we neglect the I=2.

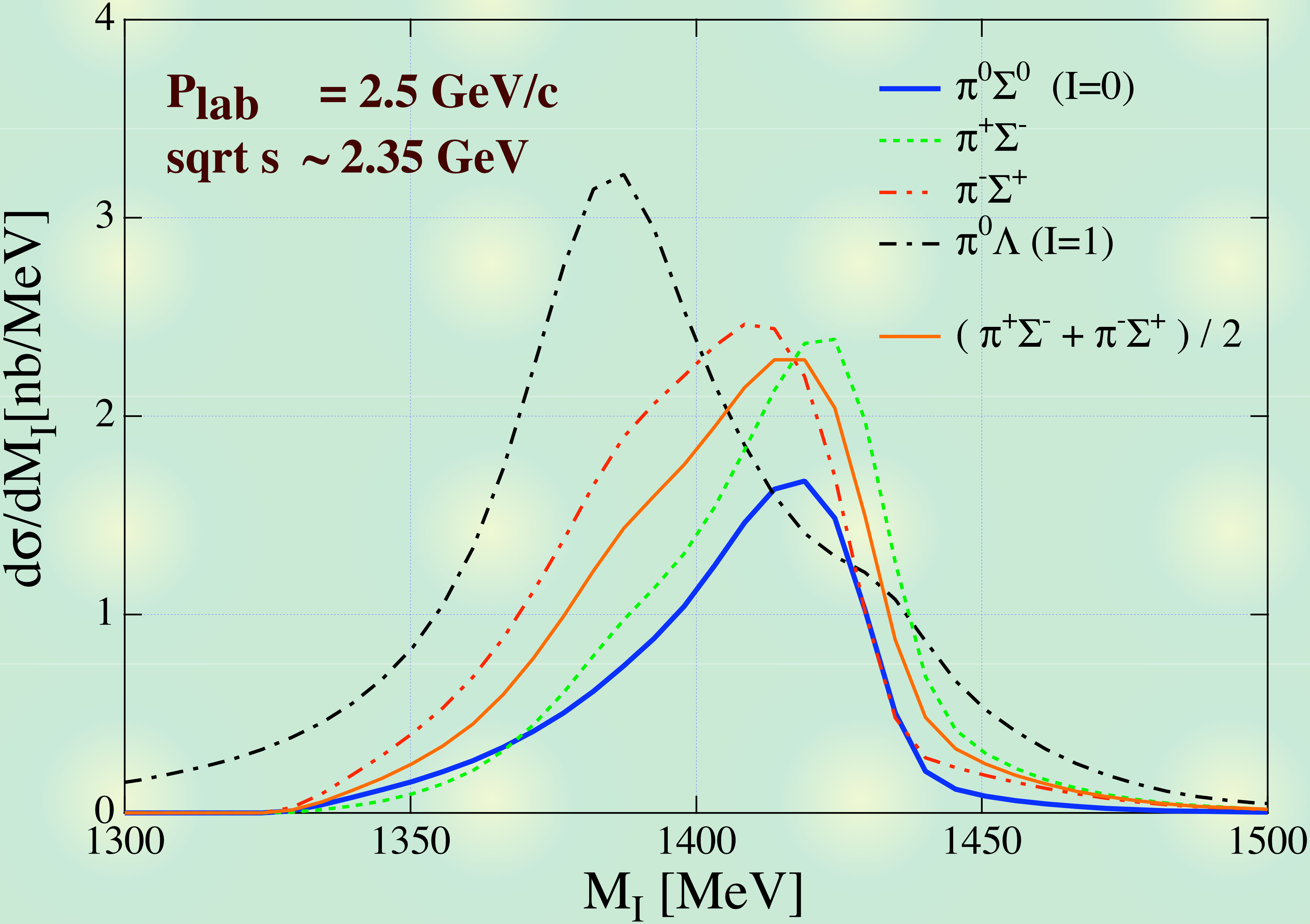
$$\frac{d\sigma(\pi^0\Sigma^0)}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2$$

- **Pure I=0 amplitude**

$$\frac{d\sigma(\pi^\pm\Sigma^\mp)}{dM_I} \propto \frac{1}{3}|T^{(0)}|^2 + \frac{1}{2}|T^{(1)}|^2 \boxed{\pm \frac{2}{\sqrt{6}}\mathrm{Re}(T^{(0)}T^{(1)*})}$$

- **Difference among charged states**
  -> when summed up, this term vanishes

Invariant mass distributions



Summary

We study the structure of Λ(1405) using the chiral unitary model.

- **There are two poles of the scattering amplitude around nominal Λ(1405).**
- **In the $\gamma p \to K^* \Lambda(1405)$ reaction, Charged πΣ states isolate the higher energy pole.**
- **Neutral πΣ state gives a clear I=0 distribution.**

T. H., A. Hosaka, E. Oset, M. J. Vicente Vacas, nucl-th/0401051